

NDIA NAVAL INTEROPERABILITY WORKSHOF



Aegis Combat System Interoperability -Designing, Building and Testing

Orlando Carvalho



Naval Electronics & Surveillance Systems-Surface Systems Moorestown, New Jersey

Outline

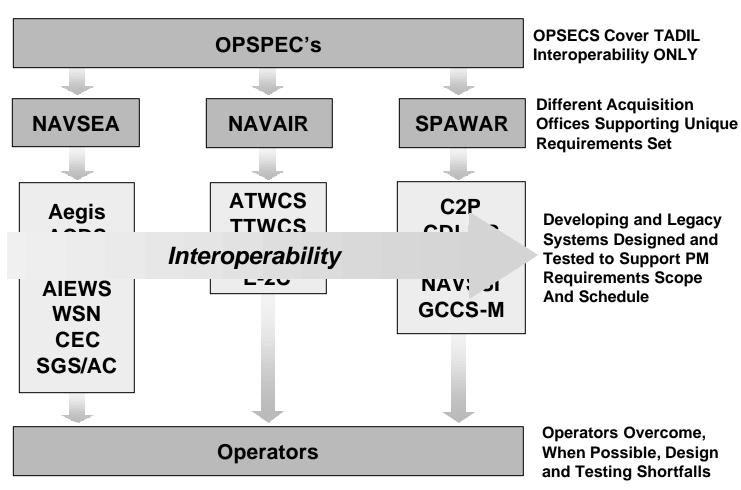


- Aegis Combat System Engineering Agent (CSEA) View
- Aegis Baseline 6 III Interoperability Initiatives
- Lessons Learned and Shortfalls
- **■** Summary

Aegis CSEA View



Interoperability Must Cut Across Developing Systems to Localize and Resolve Problems Before Delivery



System Development "Business As Usual" will <u>Not</u>
Achieve Interoperability Improvement

Background



- CEC OPEVAL events led to formation of an Interoperability Task Force Senior System Engineering Council
 - Tasked to resolve System problems, point solution for CEC OPEVAL
 - ITF Link/ID/Interoperability team investigated 166 problems and corrected 38 over 17 months
- Concurrently PMS 400B asked, How can we improve interoperability during development?
- Lockheed Martin developed new test initiative to identify and correct interoperability problems during Baseline 6 Phase III development

Interoperability Improvement Required Infrastructure and Process Changes, I.e. Not "Business As Usual"

New Test Initiative – What to Do?

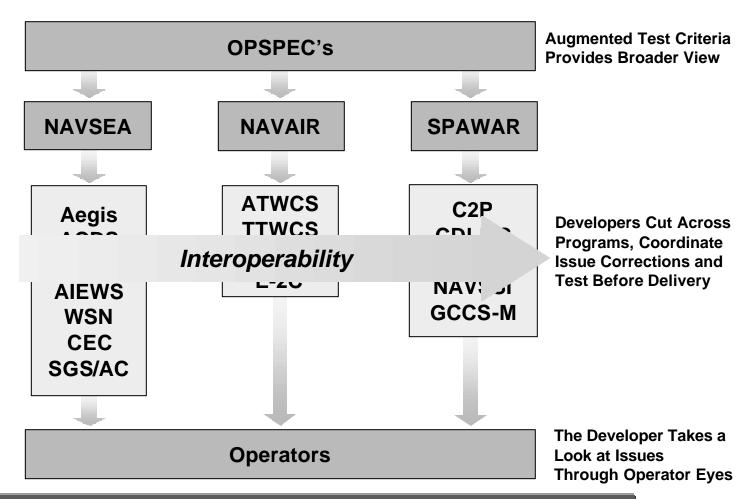


- Develop a system test infrastructure that would stimulate multiple systems during development
 - An infrastructure that supported:
 - □ an ability to generate and distribute common dynamic tracks to be processed by multiple systems.
 - □ computer generated scenarios that would replicate operationally based experience.
- Develop a robust test criteria with quantitative performance measurements
- Develop test methodologies that facilitate:
 - Iterative cross system problem identification
 - Coordinated developer investigation
 - System wide problem resolution and validation

Move Away From Sterile Single Ship Test Environments, Validating S/W Requirements.... Move towards Testing The Way The Ship Fights

New Test Initiative – How To Do It





Interoperability Can Be Measured and Tested by Developers

Multi-Aegis Combat System (MACS)

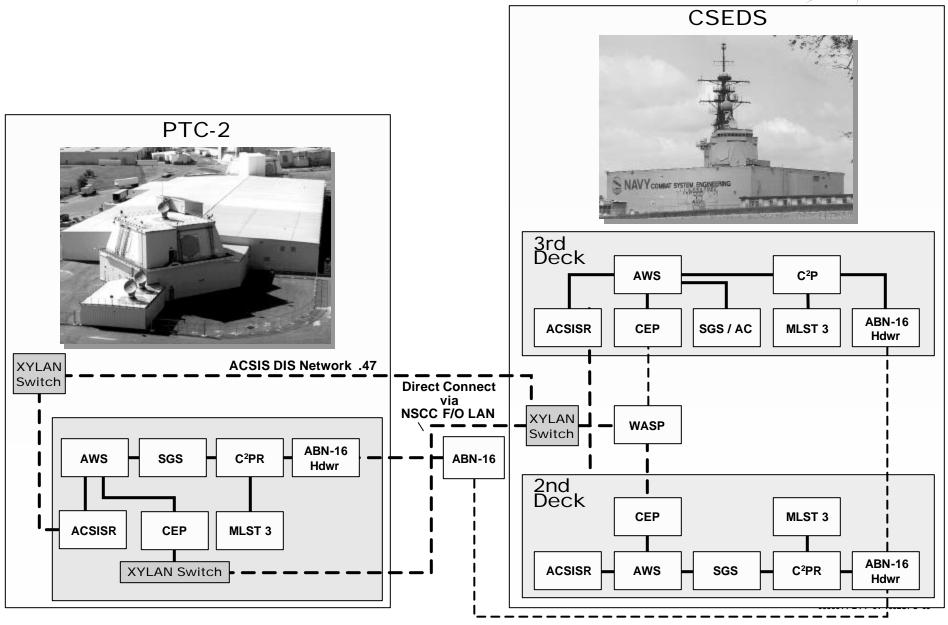


- High-fidelity interoperability testing using operationally based scenarios on a distributed network
 - Distribute tracks via Distribute Interface Simulator (DIS)
 - Connect TADILS via Aegis Broadcast Network (ABN-16)
 - Connect CEC via secure LAN
- Supplements
 - □ Navy Link Certification
 - □ Link exercises with Patriot/THAAD,E-2, ACDS
- Provides
 - □ Common sensor environment
 - Multi-aircraft , Multi-TBM
 - Simultaneous AAW and TBM

Built Battle Force Rancocas

Battle Force Rancocas

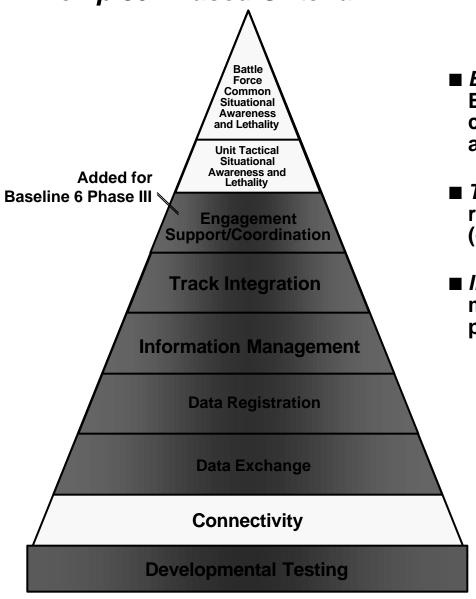




MACS Interoperability Test Goals



Temp 801 Based Criteria



Level Definition (Abridged)

- Engagement Support/Coordination: Exploitation of integrated tack data and connectivity to support and coordinate air/TBM engagements
- Track Integration: The fusion of local and remote sensor data and track parameters (correlation, decorrelation, mutual tracking)
- Information Management: The storage and management of local and remote track parameter data (ID, IFF, etc.)
 - Data Registration: The corrective alignment of local and remote track position and kinemetic data
 - Data Exchange: The sharing of data at the element and unit level
 - Developmental Testing: Verification of MACS test architecture and procedures

Test Process



Select Test Goal(s); Start at Bottom of Pyramid

Problem Correction Received; System Wide Problem Correction / Verification

Select Scenario; Recreated Operation Scenario

> Configure Combat Systems

Conduct
Test, Collect
Data;
Coordinated
MultiSystem
Events

Data Analysis and
Problem DocuMentation;
System Wide
Data
Analysis





T. Baseline AAW 1. Single threat (bandit A) 2. Single threat (bandit B) 1. Baseline AAW 2. Single threat (bandit B) 3. Dual threat (bandit A B) 2. Baseline AAW mode swap 2. Single threat (bandit A B) 2. Baseline AAW mode swap 3. Dual threat (bandit B) 2. Baseline AAW mode swap 3. Dual threat (bandit B) 3. Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 1. Single ASCM salvos 4. Four ASCM salvos 5. Baseline HVA AAW 2. Four ASCM salvos 5. Baseline HVA AAW 3. Court ASCM salvos 4. A2.5 GP A2.5 GP A2.6 GP A2.7 GP A2.7 GP A2.8 GP A2.9 GP A2	Scenario	Permutation	Section	Recommended script name
1. Baseline AAW 2. Single threat (bandit B) 3. Dual threat (bandit A & B) 2. Baseline AAW 3. Dual threat (bandit A) 4. Single threat (bandit A) 2. Baseline AAW 3. Dual threat (bandit A) 4. Single threat (bandit A) 2. Baseline AAW 4. Single threat (bandit A) 3. Dual threat (bandit B) 4. Single threat (bandit A) 4. Single threat (bandit A) 5. Baseline AAW 6. Single threat (bandit A) 6. Single ASCM 6. Single threat (bandit A) 6. Single threat (bandi	1. Baseline AAW	1. Single threat	A2.1.1.1	6P3_INT_BASE_AAW1
1. Baseline AAW 2. Baseline AAW (bandit A & B) 2. Baseline AAW (bandit A) 2. Baseline AAW (bandit A) 2. Single threat (bandit B) 2. Baseline AAW (bandit B) 2. Baseline AAW (bandit B) 3. Dual threat (bandit B) 3. Dual threat (bandit B) 4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 1. Two ASCM salvos 5. Baseline HVA AAW 2. Four ASCM salvos 4. Solva A2.5 5. Baseline HVA AAW 4. Four ASCM salvos 4. Solva A2.5 6. Four ASCM salvos 4. Solva A2.6 6. Four ASCM salvos 5. Baseline HVA AAW 4. Four ASCM salvos 5. Baseline HVA AAW 5. Four ASCM salvos 6. Four ASCM salvo		(bandit A)		
1. Baseline AAW (bandit A & B) 2. Baseline AAW (bandit A) 2. Baseline AAW (bandit A) 2. Baseline AAW (bandit A) 3. Dual threat (bandit B) 2. Baseline AAW (bandit B) 3. Dual threat (bandit A & B) 3. Dual threat (bandit A & B) 3. Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 5. Baseline HVA AAW 7. Four ASCM Salvos 5. Baseline HVA AAW 7. Four ASCM Salvos 5. Baseline HVA AAW 7. Four ASCM Salvos 8. Fo	1. Baseline AAW	2. Single threat	A2.1.3.1	6P3_INT_BASE_AAW2
(bandit A & B) 2. Baseline AAW (bandit A) 2. Baseline AAW (bandit B) 2. Baseline AAW (bandit B) 2. Baseline AAW (bandit B) 3. Dual threat (bandit A & B) 3. Dual-Axis AAW (bandit A & B) 3. Dual-Axis AAW (bandit A & B) 4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 7. Three ASCM salvos 4. Modified Dual-Axis AAW threat 8. Modified Dual-Axis AAW threat 9. Modifie	`\			\
2. Baseline AAW (bandit A) 2. Baseline AAW (bandit A) 2. Baseline AAW (bandit B) 3. Dual threat (bandit A & B) 3. Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 5. Baseline HVA AAW 5. Baseline HVA AAW 7. Baseline HVA AAW 7. Baseline HVA AAW 8. Carrow ASCM (A2.4) 8. Carrow ASCM (A2	1. Baseline AAW	· · · · · · · · · · · · · · · · · · ·	A2.1.3.2	6P3_INT_BASE_AAW3
mode swap 2. Baseline AAW mode swap (bandit B) 2. Baseline AAW mode swap 3. Dual threat (bandit A & B) 3. Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 1. Two ASCM salvos 5. Baseline HVA AAW 2. Four ASCM salvos 4. Four ASCM salvos 4. Four ASCM salvos 4. Four ASCM salvos 5. Baseline HVA AAW 2. Four ASCM salvos 4. Four ASCM salvos 4. Four ASCM salvos 4. Four ASCM salvos 5. Baseline HVA AAW 2. Four ASCM salvos 4. Four ASCM salvos 4. Four ASCM salvos 5. Baseline HVA AAW 5. Baseline HVA AAW 5. Baseline HVA AAW 6. Four ASCM salvos	`\	(bandit A & B)	 -	
2. Baseline AAW (bandit B) 2. Baseline AAW (bandit B) 3. Dual threat (bandit A & B) 3. Dual-Axis AAW (bandit A & B) 4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 7. Baseline HVA AAW 7. Baseline HVA AAW 8. Baseline	2. Baseline AAW	1. Single threat	A2.2.1.1	6P3_INT_BASE2_AAW1
mode swap (bandit B) 2. Baseline AAW mode swap 3. Dual threat (bandit A & B) 3. Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 1. Two ASCM salvos 4. Four ASCM salvos 4. Four ASCM salvos 5. Baseline HVA AAW 2. Four ASCM salvos 4. Four ASCM salvos 4. Four ASCM salvos 4. Four ASCM salvos 6. Four ASCM salvos	mode swap	(bandit A)		
2. Baseline AAW mode swap 3. Dual threat (bandit A & B) 3. Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 1. Two ASCM salvos 5. Baseline HVA AAW 2. Four ASCM salvos 4. Solvos A2.4 6P salvos A2.5 6P salvos A2.6 P salvos A2.7 Solvos A2.8 Solvos A2.8 Solvos A2.9 Solvos		_	A2.2.3.1	6P. □ Data Miles
mode swap (bandit A & B) 3. Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 1. Two ASCM Salvos 4. Four ASCM Salvos 5. Baseline HVA AAW 2. Four ASCM Salvos 4. Four ASCM Salvos 4. Four ASCM Salvos 5. Baseline HVA AAW 4. Four ASCM Salvos 5. Baseline HVA AAW 4. Four ASCM Salvos 5. Baseline HVA AAW 7. Keep out A A3 8. Four ASCM Salvos 6. Four ASCM Salvos 7. Four ASCM Salvos 7. Four ASCM Salvos 8. Four ASCM Sa	,	· · · · · · · · · · · · · · · · · · ·		
mode swap (bandit A & B) 3. Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 5. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 1. Two ASCM Salvos 5. Baseline HVA AAW 2. Four ASCM Salvos 4. Four ASCM Salvos 5. Baseline HVA AAW 2. Four ASCM Salvos 4. Four ASCM Salvos 4. Four ASCM Salvos 5. Baseline HVA AAW 4. Four ASCM Salvos 5. Baseline HVA AAW 4. Four ASCM Salvos 5. Baseline HVA AAW 7. WPB# WPD# WPD# WPD# WPD# WPD#		0 0.0	A2.2.3.2	
threat 4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis Salvos 5. Baseline HVA AAW 5. Baseline HVA AAW 7. WP A# WP A# WP C# WP M# WP M#		· · · · · · · · · · · · · · · · · · ·		<u> </u>
threat 4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 1. Two ASCM Salvos 4. Four ASCM Salvos 4. Four ASCM Salvos 5. Baseline HVA AAW 2. Four ASCM Salvos 4. Four ASCM Salvos 5. Baseline HVA AAW 4. Four ASCM Salvos 4. Four ASCM Salvos 5. Baseline HVA AAW 4. Four ASCM Salvos 4. Four ASCM Salvos 4. Four ASCM Salvos 5. Baseline HVA AAW 5. Baseline HVA AAW 6. Four ASCM Salvos 7. Four ASCM Salvos 8. Four ASCM Salvos		N/A	A2.3	
AAW threat 4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 6. A2.4 6. A2				⊥ Y°
4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 5. Baseline HVA AAW 2. Two ASCM Salvos A2.4 6P A2.4 6P A2.5 6P Salvos A2.6 6P Salvos A2.7 6P WP M# WP M# WP M# WP M#			A2.4	6P∮
4. Modified Dual-Axis AAW threat 4. Modified Dual-Axis salvos 4. Four ASCM salvos 5. Baseline HVA AAW 7. Two ASCM salvos 5. Baseline HVA AAW 2. Four ASCM salvos A2.4 6P				50
4. Modified Dual-Axis AAW threat salvos 4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 1. Two ASCM salvos 5. Baseline HVA AAW 2. Four ASCM salvos 4. Four ASCM salvos 4. Four ASCM salvos 4. Four ASCM salvos 6. Four ASCM salvos 7. Four ASCM salvos 6. Four ASCM salvos 6. Four ASCM salvos 7. Four ASCM salvos 6. Four ASCM salvos 7. Four ASCM salvos 6. Four ASCM salvos			A2.4	6Pt a MACSUNITE
AAW threat 4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 1. Two ASCM salvos 4. Four ASCM salvos A2.4 6P WPA# WPA# WP WP B# Salvos 4. Four ASCM salvos 6P Salvos 4. Four ASCM Salvos 6P WP M#		` `		
4. Modified Dual-Axis AAW threat 5. Baseline HVA AAW 1. Two ASCM salvos 5. Baseline HVA AAW 2. Four ASCM salvos 4. Four ASCM salvos 6. Baseline HVA AAW A2.5 6. Baseli			A2.4	1 1 1 2
AAW threat salvos 5. Baseline HVA AAW 1. Two ASCM salvos 5. Baseline HVA AAW 2. Four ASCM salvos 6P salvos 42.5 6P wP A# WP A# WP C# wP WP M#			10.1	A2 A1 / 6
5. Baseline HVA AAW 1. Two ASCM salvos 5. Baseline HVA AAW 2. Four ASCM salvos A2.5 6P WP B# WP C# Salvos WP M#			A2.4	
salvos 5. Baseline HVA AAW 2. Four ASCM salvos A2.5 6P 45 WP C# WP C# WP M#				2 ^Δ
5. Baseline HVA AAW 2. Four ASCM A2.5 6P 4 WP C# Salvos	5. Baseline HVA AAW		A2.5	
salvos WP M#	5 5 11 111/4 4 4 4 4		102	
	5. Baseline HVA AAW		A2.5\	
	5. Baseline HVA AAW	3. Six ASCM salvos	A2.5	
3. Dasellie TVA AAVV 3. SIX ASCIVI Salvus A2.5 OF	5. Daseille HVA AAW	3. SIX ASCIVI Salvos	A2.5 \	\ <u>\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\</u>

Data Registration Testing:

1

An Example

- MACS test matrix identifies 11 priority link specific data registration test goals and pass/fail criteria for:
 - Relative Gridlock
 - IU Registration
 - Sensor Registration
 - Developed ACSIS DIS scenario to inject sensor error that requires compensation using data registration

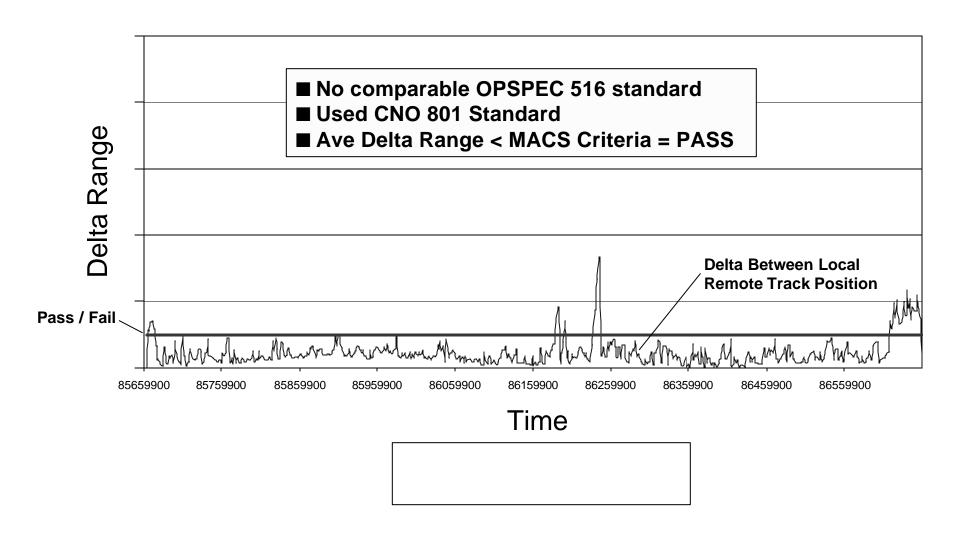
■ Initial results

- Failed on visual inspection: **Tracks jumped wildly while** conducting relative gridlock throughout scenario
- Data analysis identified C2PR N-1-3033, SGS/AC Sensor Registration application and C&D program problems
- All fixes verified
- Basic Relative Gridlock, IU Registration, and Sensor Registration functionality passed

Success Story, But Required Five Month Iterative Process

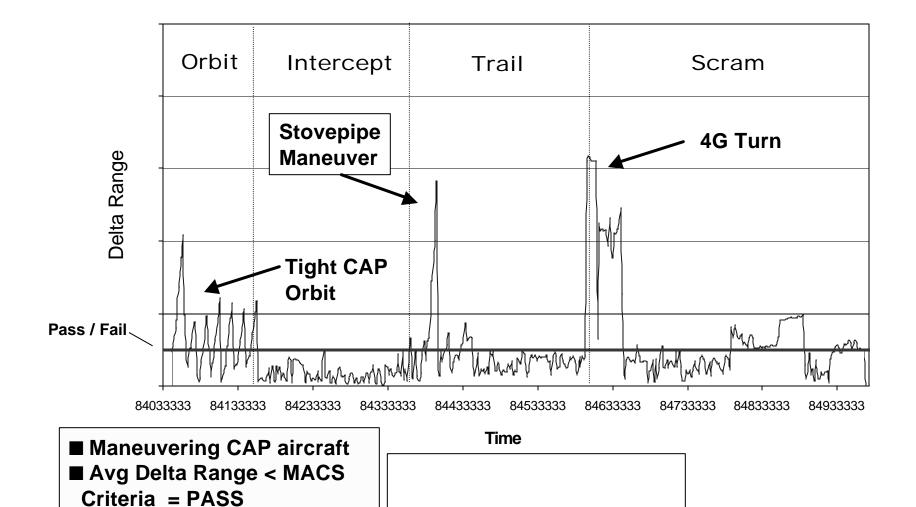
Relative Gridlock Test Result: Aegis-Aegis Mutual Track





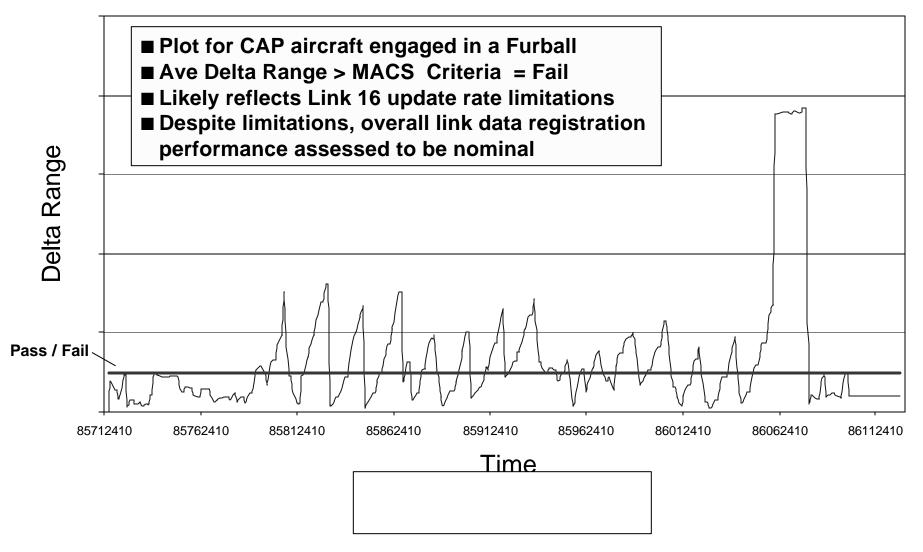
Sensor and IU Registration Results





Sensor and IU Registration Limitations





MACS Lessons Learned



- Developmental testing should be conducted in small doses with limited objectives
- Test configuration very challenging
 - Most resource intensive test configuration we employ
 - Developmental testing demands large test time investment per test objective
- Test architecture needed thorough testing and debugging
- Testing generates heavy data analysis demands
- DIS essential for TBMD interoperability testing

Finding and Fixing Interoperability Problems is an Iterative Time Consuming Process

Summary



- Lockheed Martin NE&SS-Surface Systems initiated MACS testing in response to PMS 400B direction to "improve interoperability"
- Infrastructure developed and testing in progress
- Experienced growing pains
- Testing has exposed problems that otherwise would be difficult to find or collect data on
- The use of DIS architecture has proven a necessity for TBMD interoperability testing
- Test shortfalls that affect ability to find and quickly resolve problems
 - Architecture / equipment
 - Analysis tools
 - Availability / participation of all elements developers

Interoperability is Not a Goal, It's a Process